The influence of cloud-sea ice interaction on the Arctic surface energy budget

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Interactions among aerosols, clouds, and climate of the Arctic Ocean

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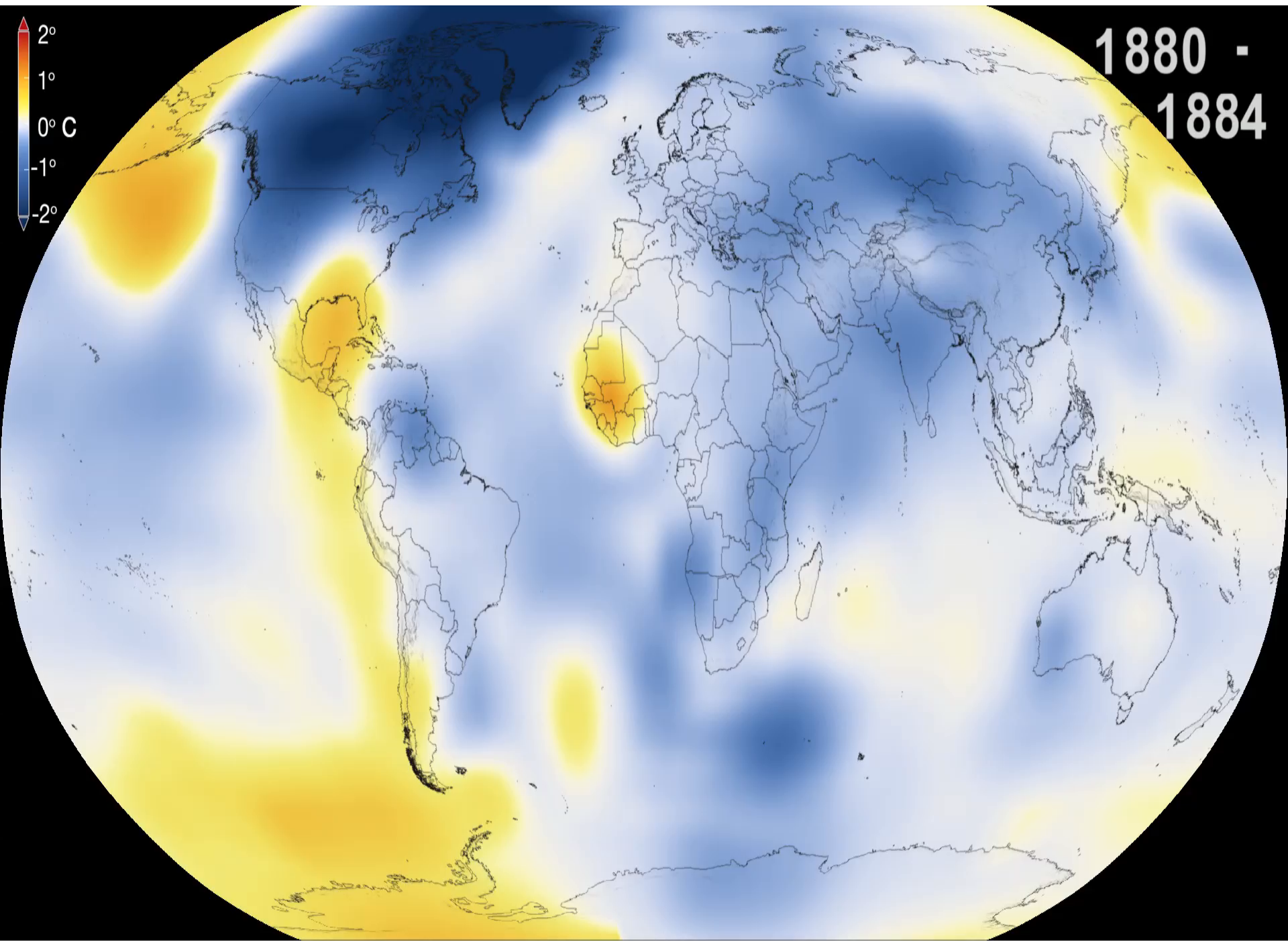
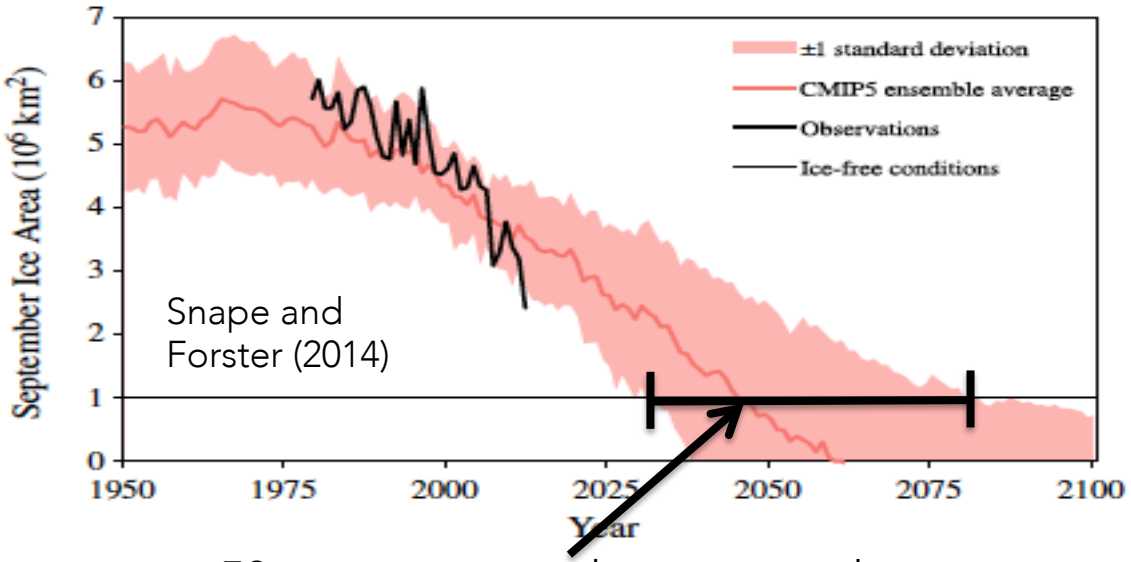
Based on the model experiments, it appears that the Arctic should be a sensitive indicator of climate change, but observational evidence of several kinds supports the opposite point of view. For example, there is no evidence of any overall sea ice retreat over the past 15 years (Chapman and Walsh, 1993). On the inter-decadal scale, Kahl et al. (1993) report no significant trend in Arctic Ocean surface temperature over the past 40 years, in contrast to the expected response to the doubling CO_2 scenario simulated by GCMs.


2°
1°
0° C
-1°
-2°
1880 -
1884

Norwegian Polar Institute, 2009

Courtesy Gary Braasch

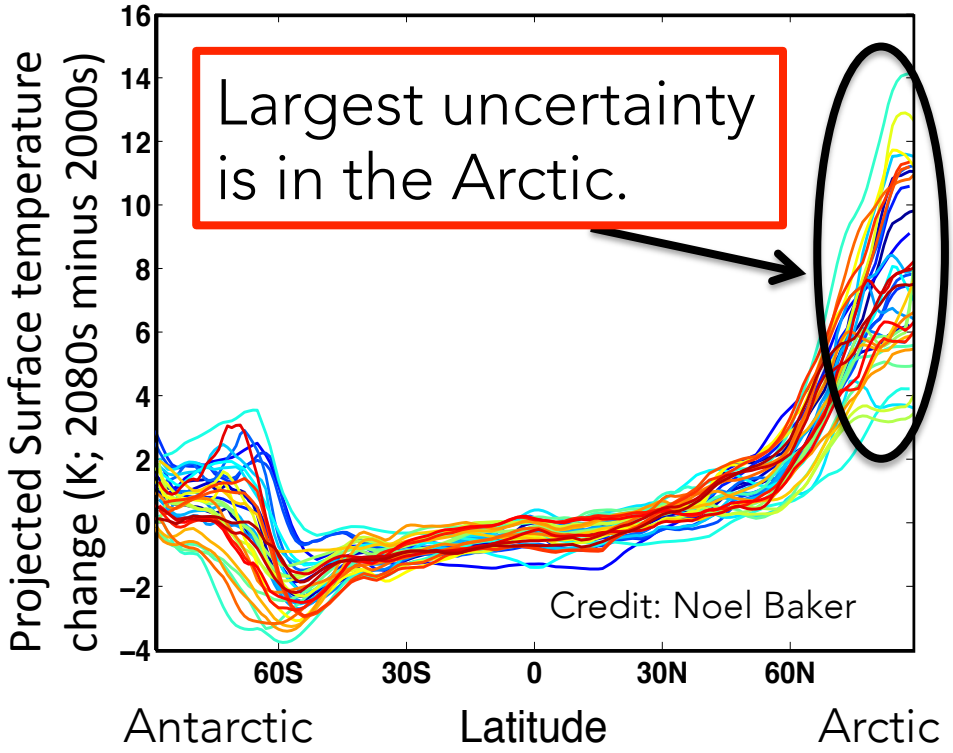
Oh, the uncertainty…



~50-year range in the projected first appearance of and ice-free Arctic

Projections of future Arctic sea ice decline and the timing of the first occurrence of a sea ice-free Arctic are very uncertain.

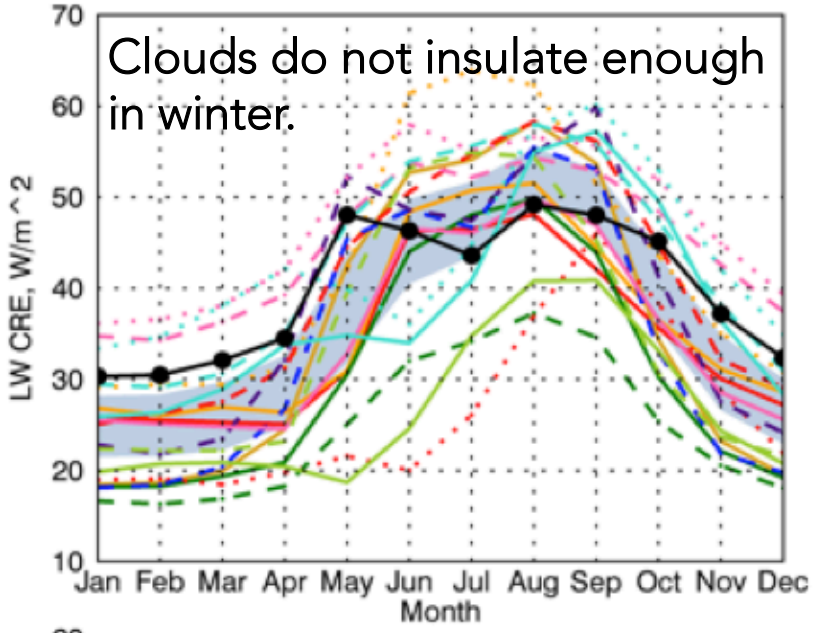
The large spread in climate model predictions of Arctic warming is attributed to model of sea ice melt and how it feeds back on the other components of the climate.

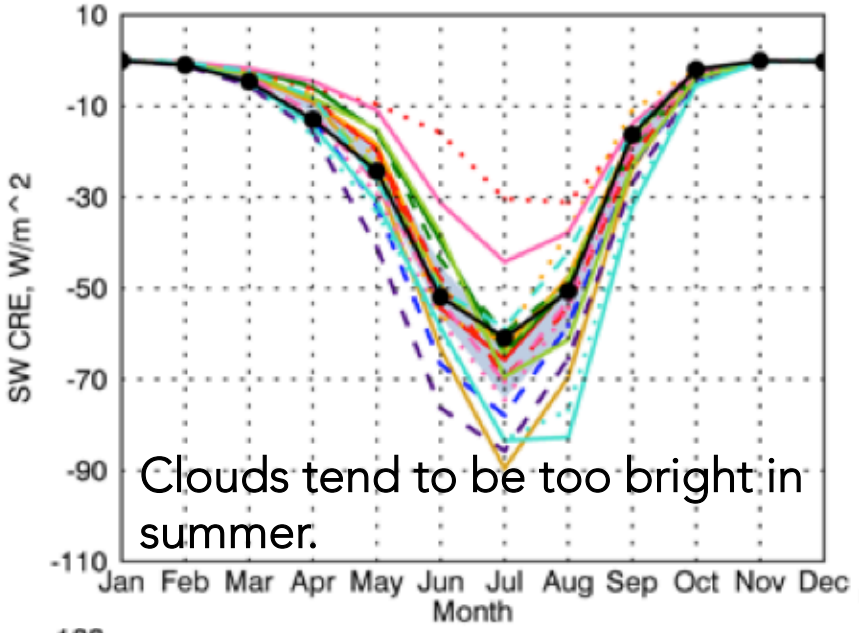


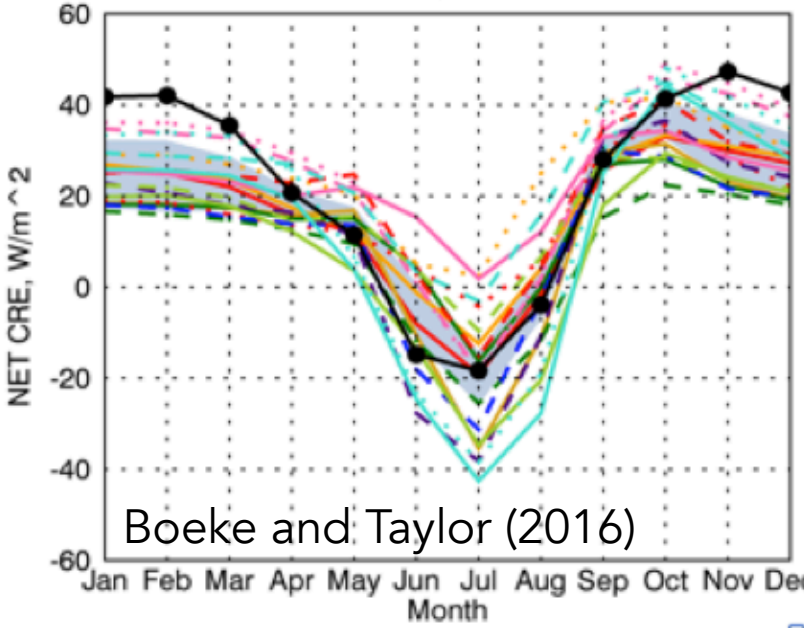
Evaluation of the Arctic surface radiation budget in CMIP5

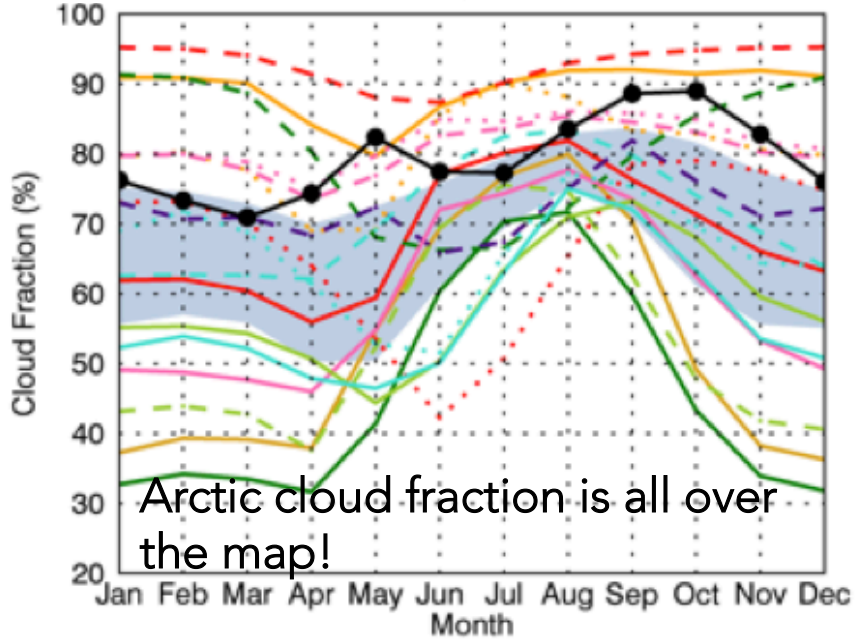
(Boeke and Taylor 2016; JGR)

CMIP5 vs. CERES Surface Cloud Radiative Effects



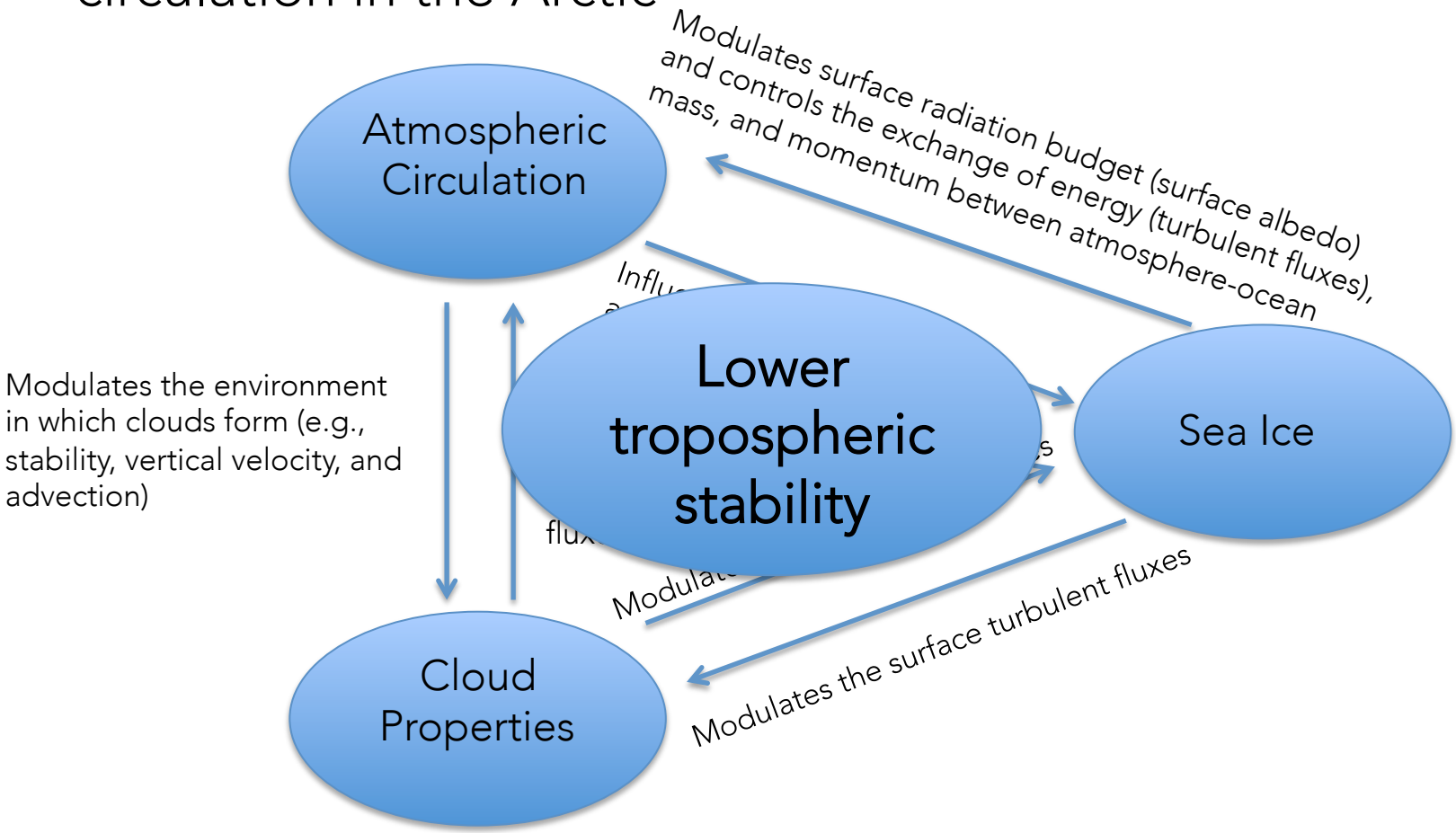






Another 3-legged stool?

Understanding the coupling between the cloud and circulation in the Arctic



In the Arctic, we cannot consider the interactions between clouds and the circulation without considering the sea ice state because sea ice influences both clouds and circulation.

Example pathways: Sea Ice-Clouds

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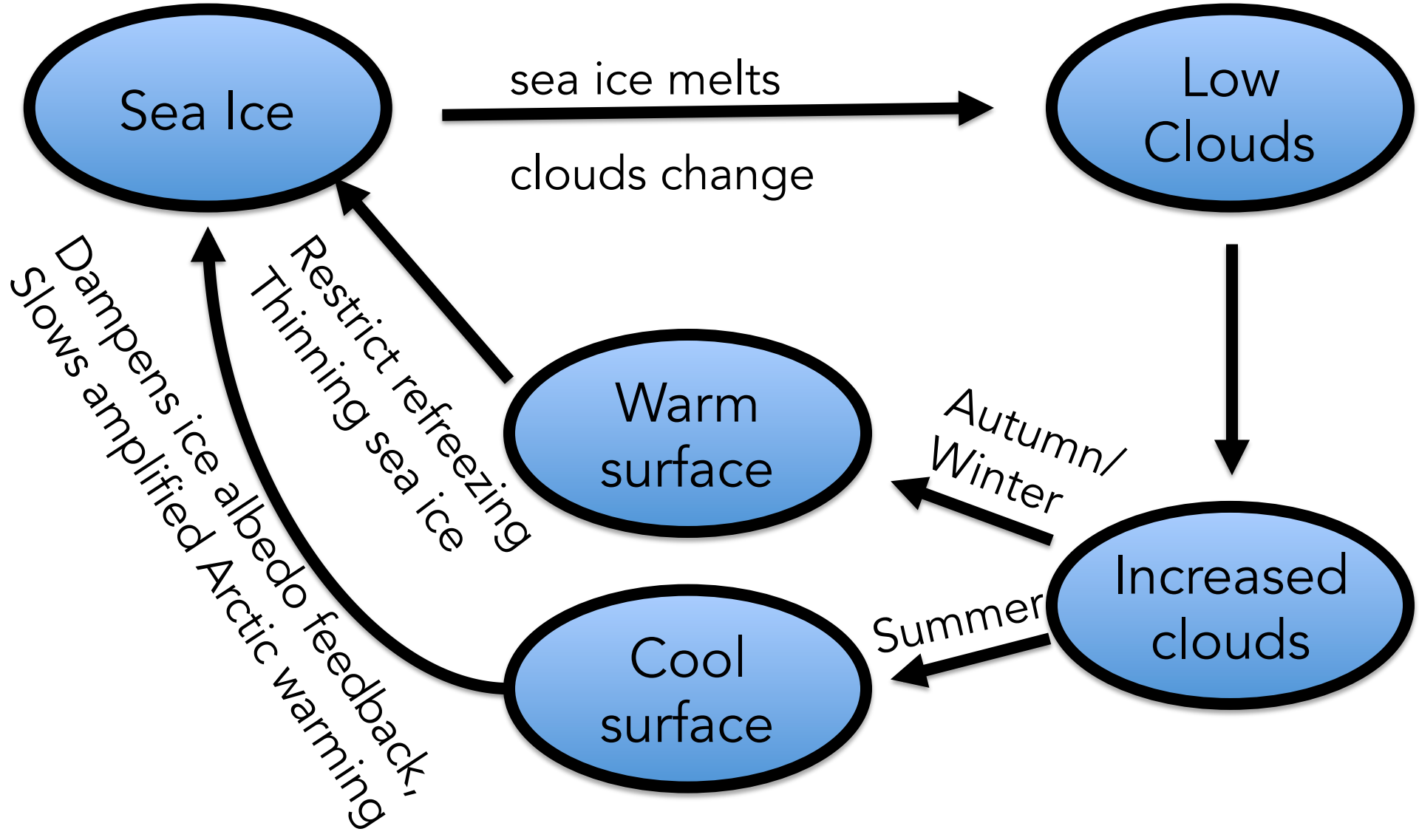
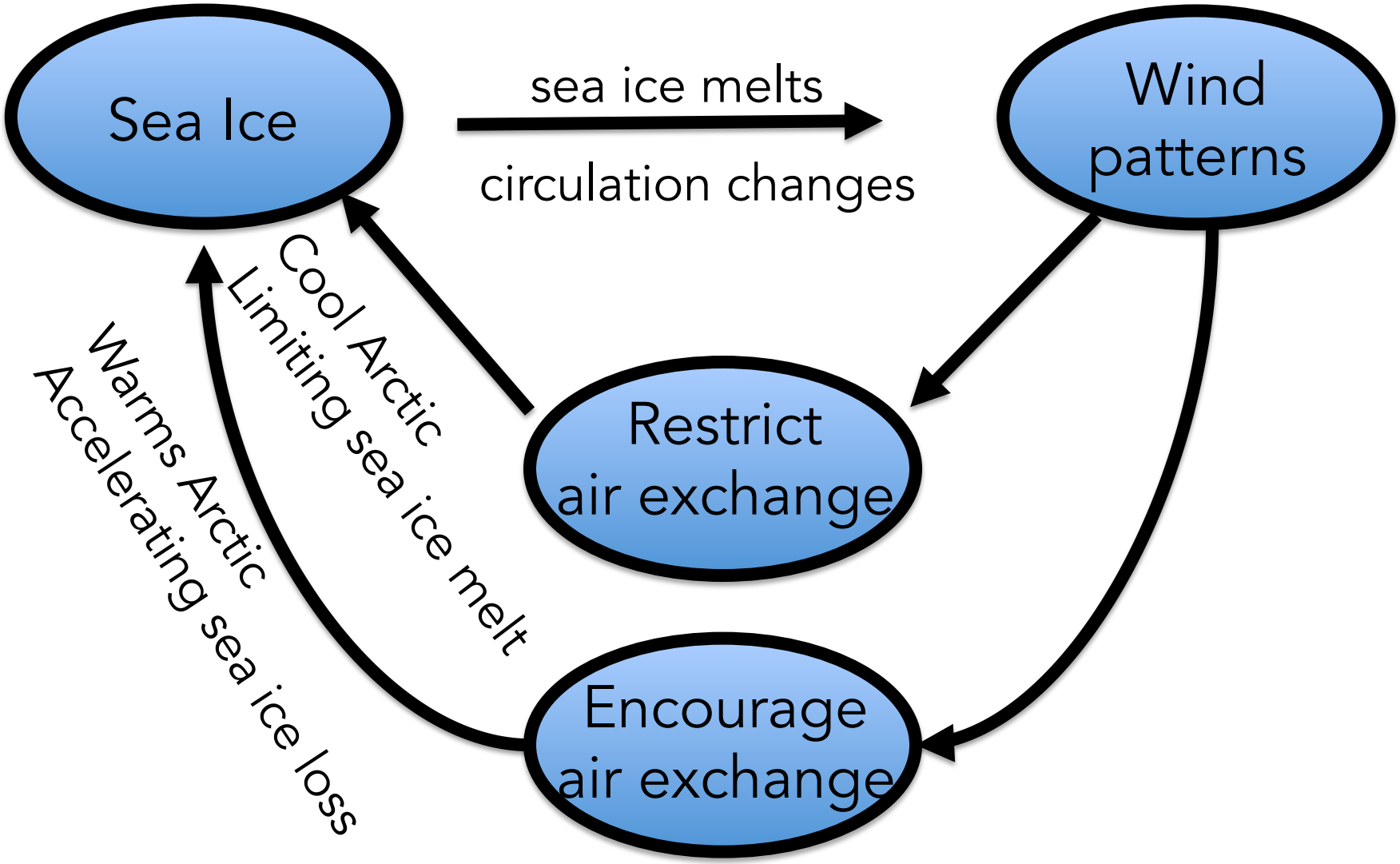


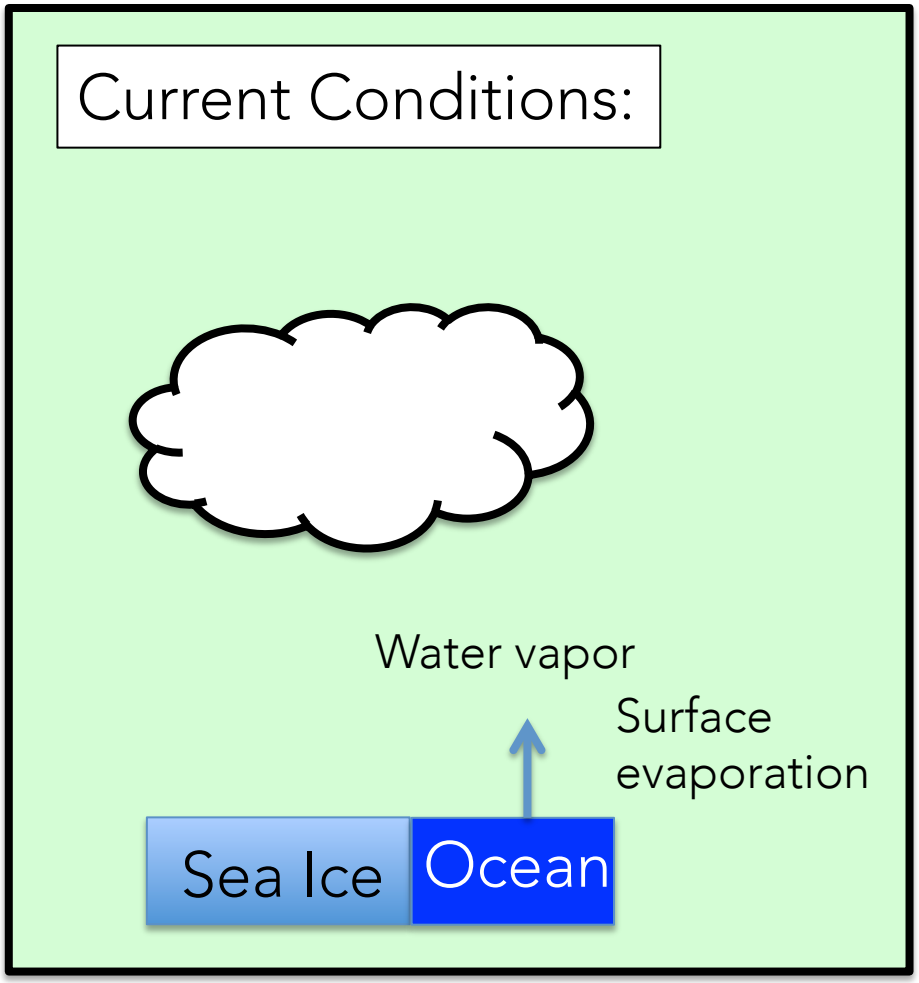
Example pathways: Sea Ice-Circulation

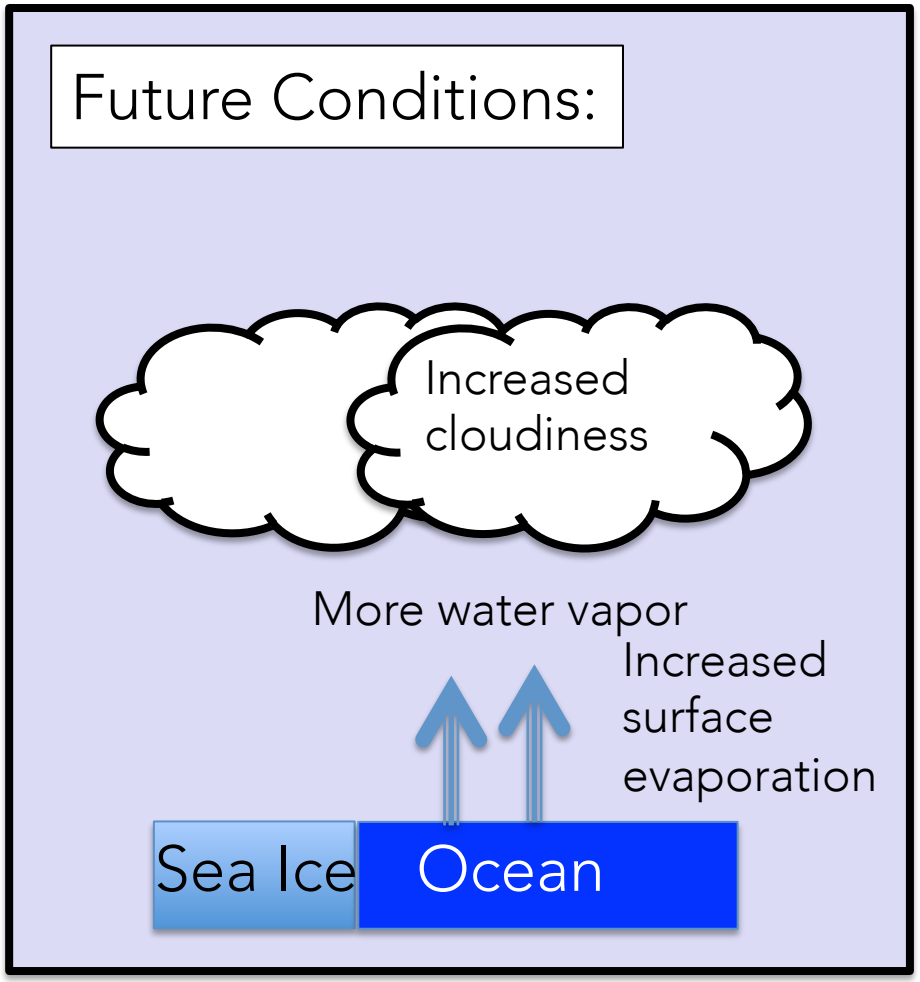


Covariance between Arctic sea ice and clouds within atmospheric state regimes at the satellite footprint level

(Taylor et al. 2015, JGR)

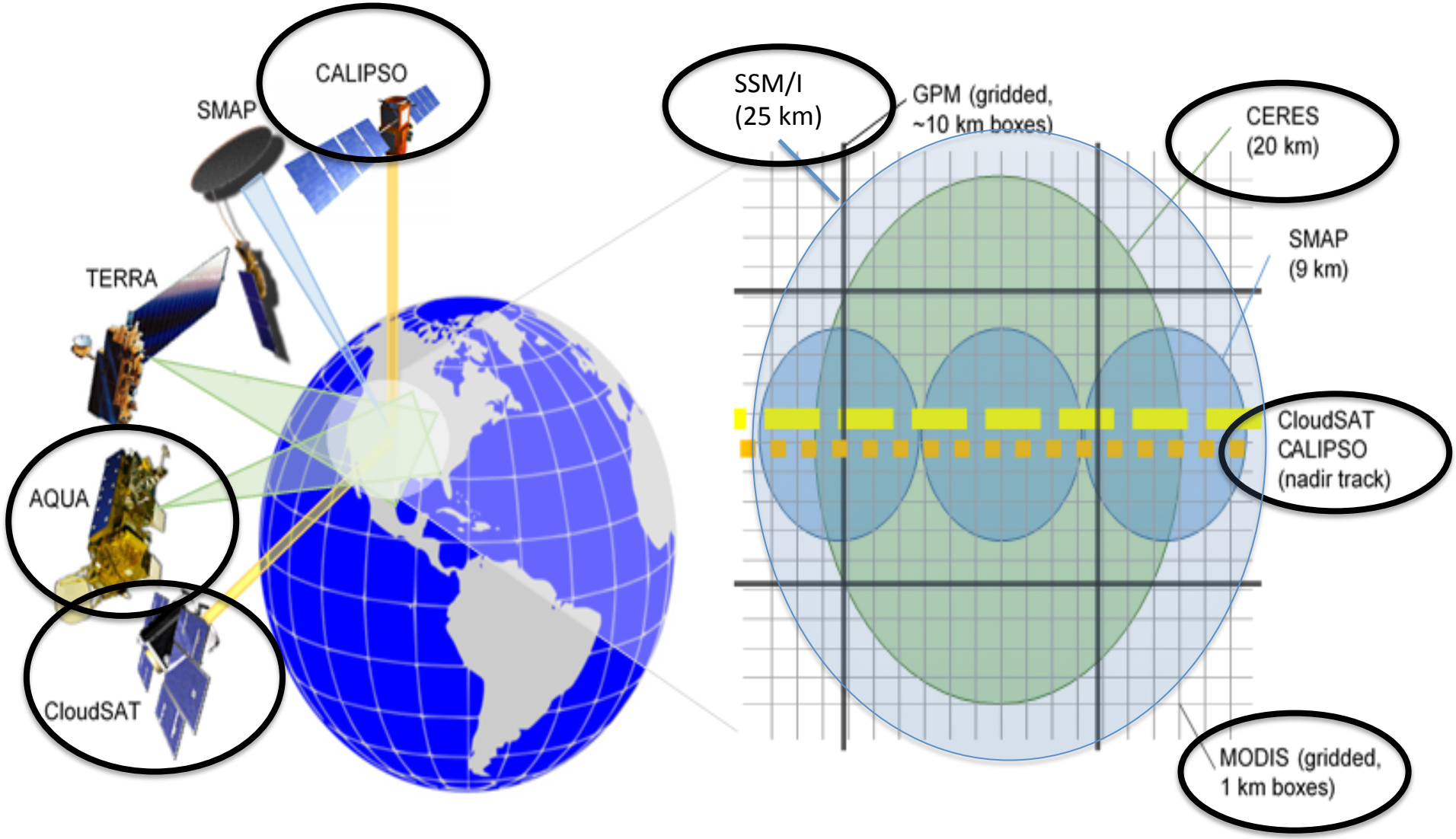
How might clouds respond to less sea ice in the Arctic?





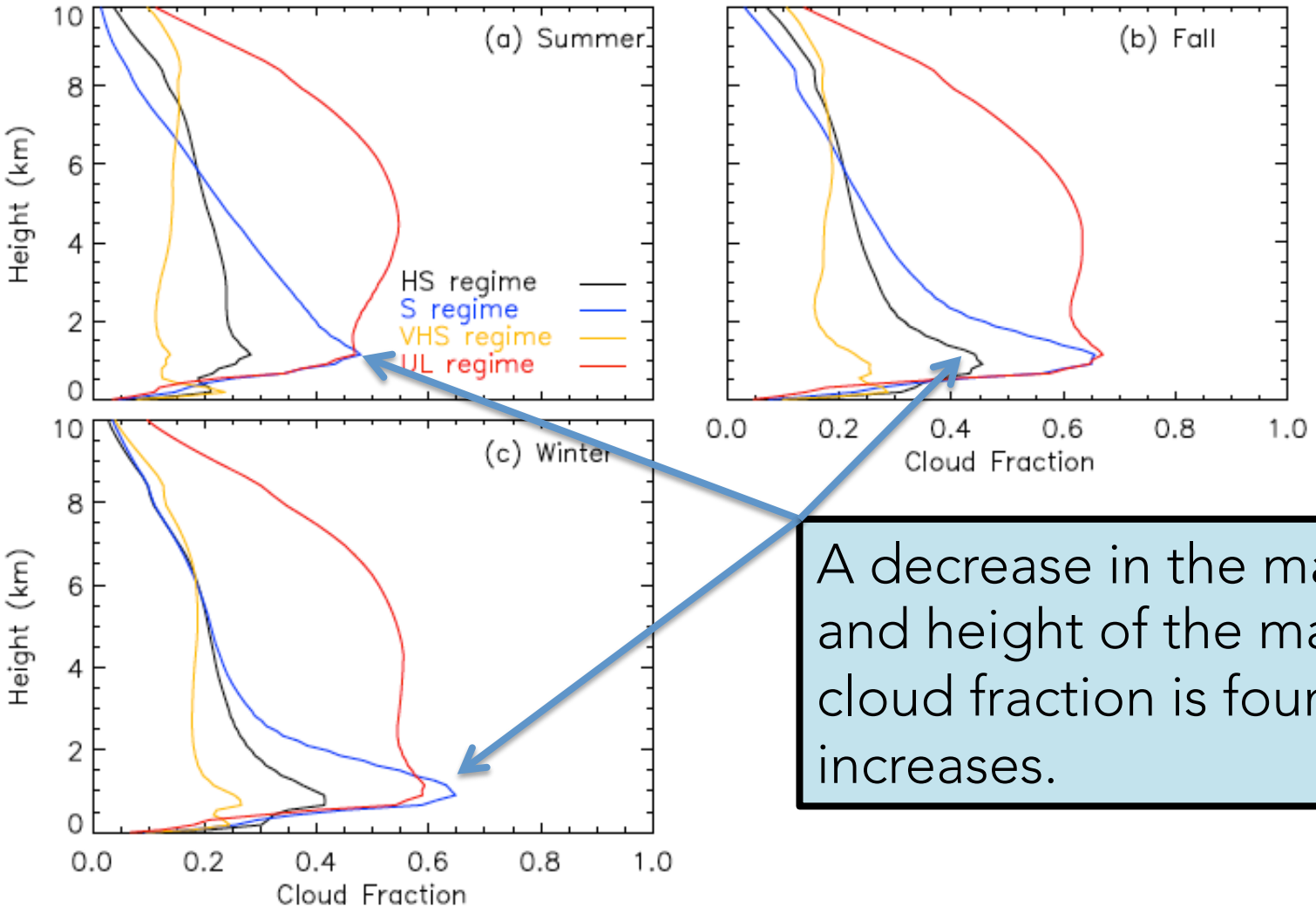
Science Question:
Do average cloud properties from instantaneous satellite observations vary with sea ice concentration?

That's the power of…Data Fusion!?



A new perspective is enabled by leveraging advances in data fusion made at NASA Langley Research Center—combining CALIPSO, CloudSAT, CERES, and MODIS.

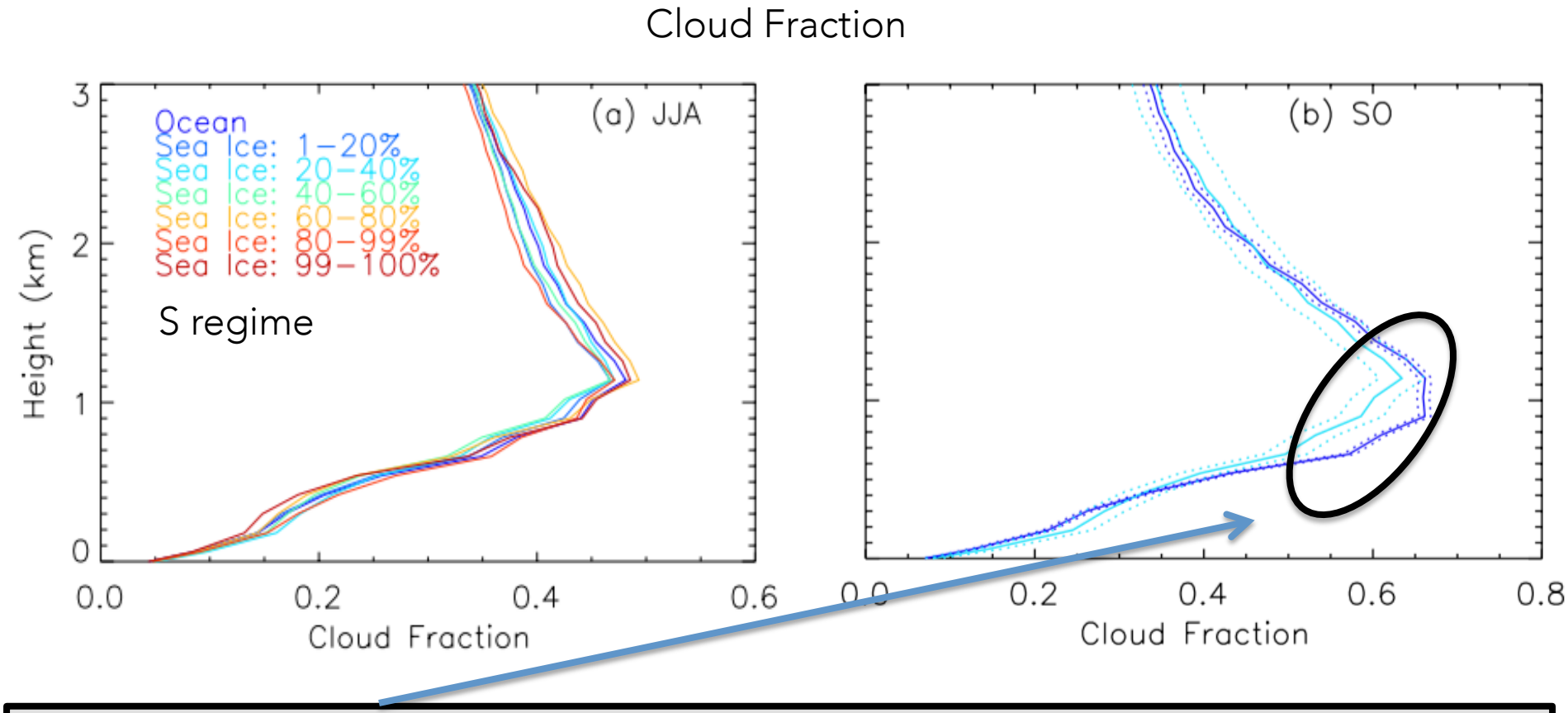
Meteorology vs. Sea ice, whose will is stronger?



A decrease in the magnitude and height of the maximum cloud fraction is found as LTS increases.

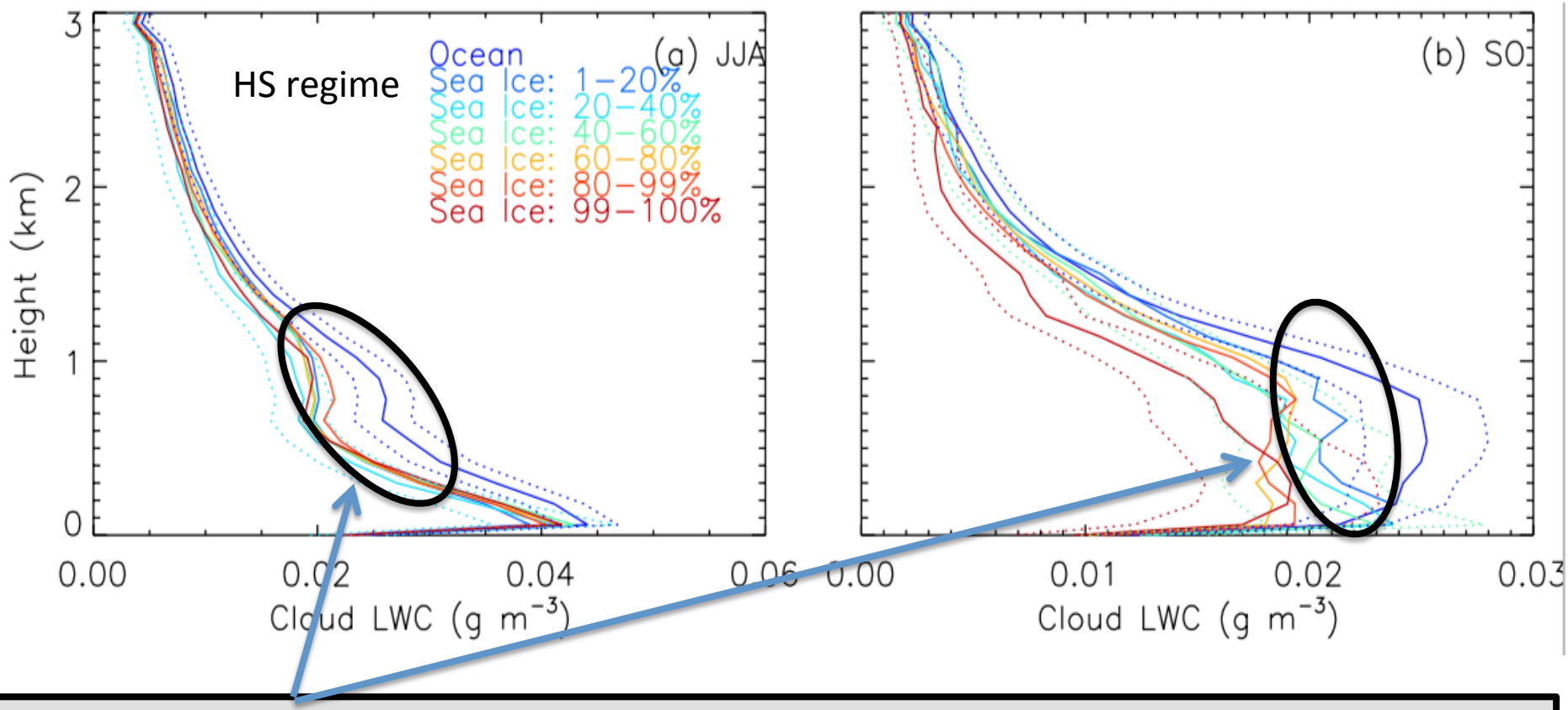
Takeaway Message: Meteorology places a strong constraint on cloud behavior.

Cloud property changes are not uniform with height



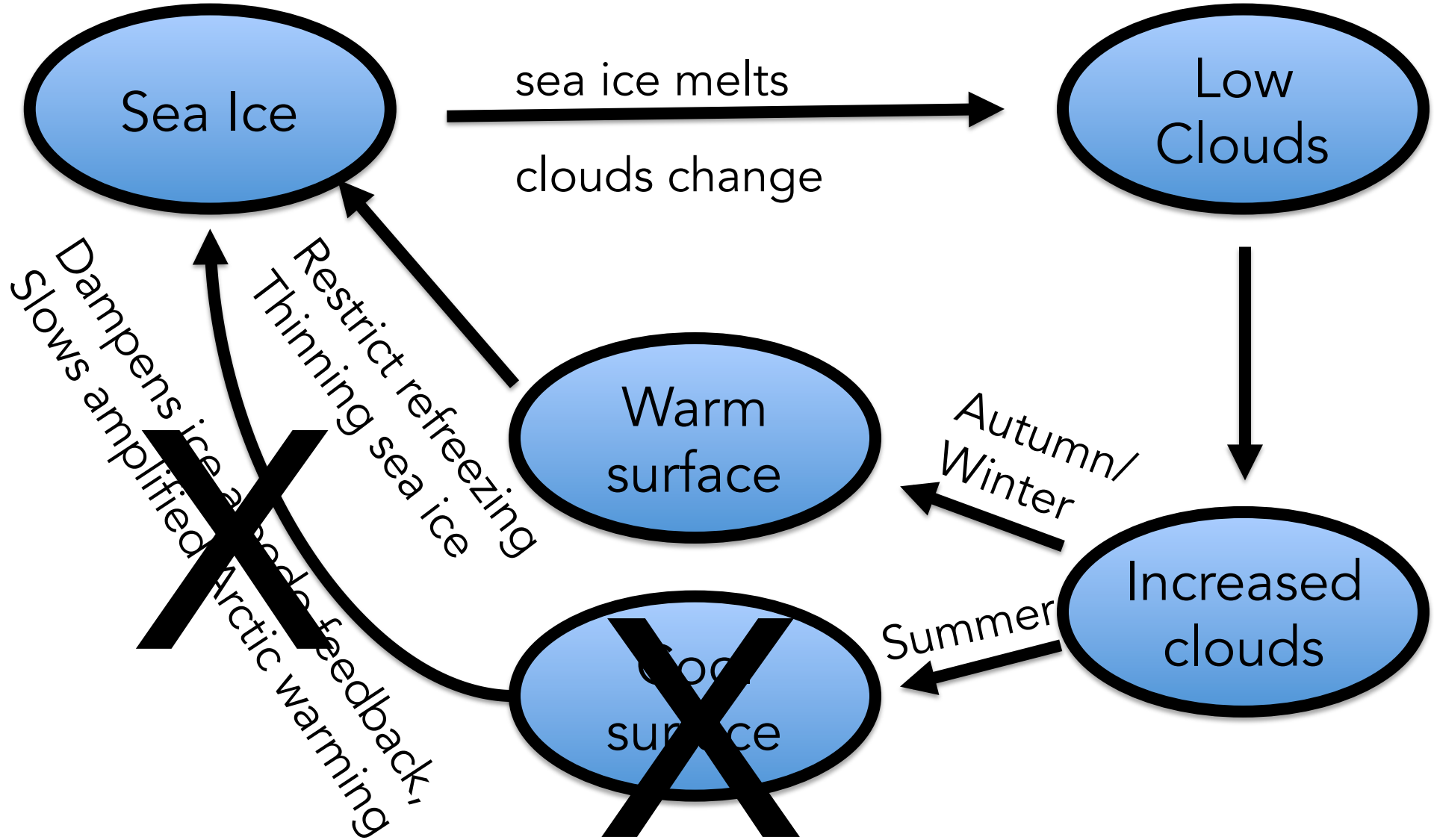
- General decrease in cloud fraction is found with increased sea ice concentration in in autumn, but no response in summer.
- Statistically significant differences at the 95% confidence interval are found at between 500 m and 1.2 km in autumn at 0% and 20-40% sea ice concentration.

LWC changes are not uniform with height



- General decrease in LWC is found with increased sea ice concentration in both summer and autumn.
- Statistically significant differences the LWC between 500 m and 1.2 km are found in summer and autumn at 0% and 20-40% sea ice concentration.

Example pathways: Sea Ice-Clouds



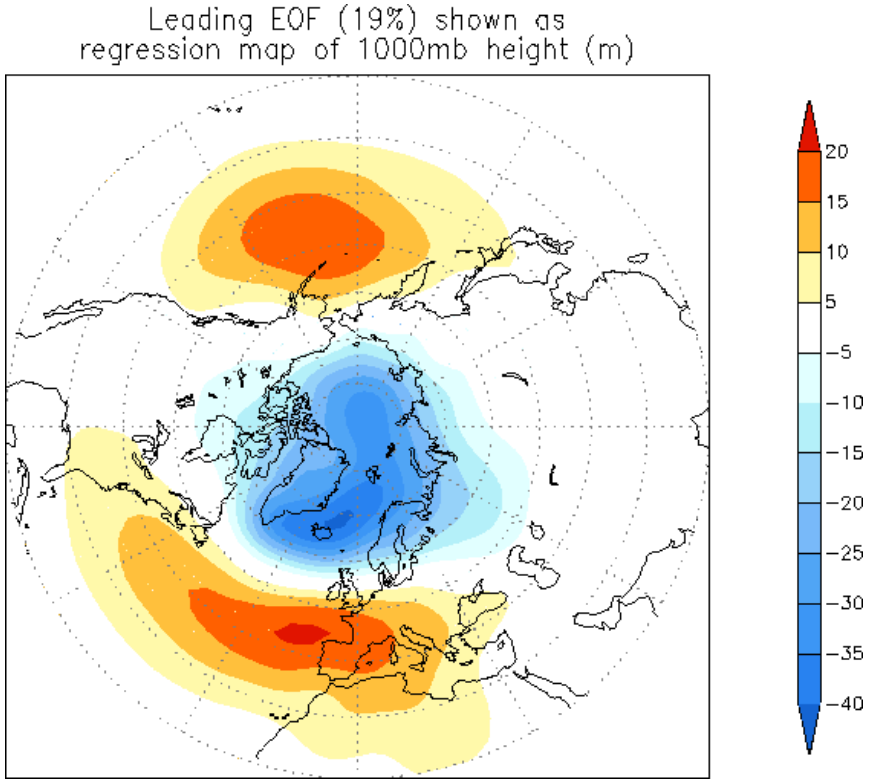
Atmospheric circulation variability influences the wintertime Arctic surface radiation budget

Hegyi and Tayor (GRL; in prep.)

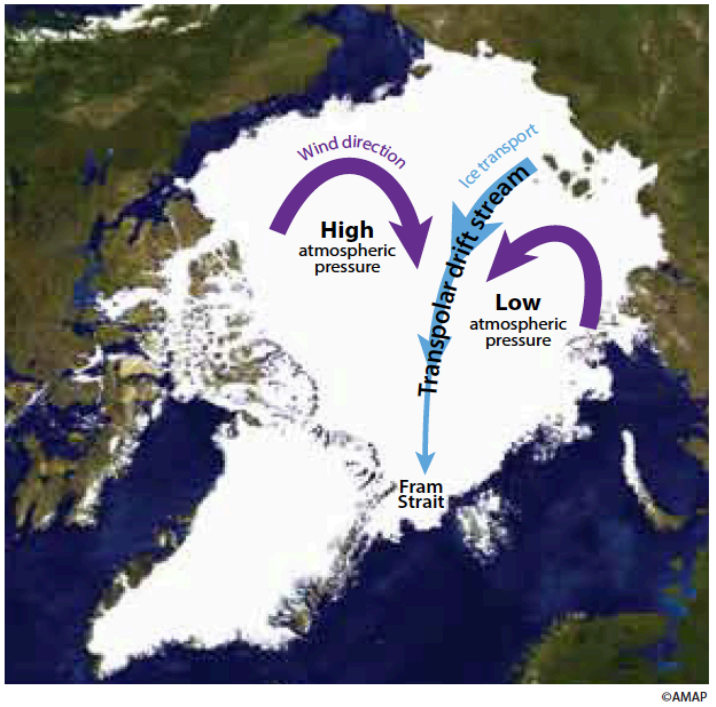
Defining the Arctic circulation

AO: Leading EOF of the 1000 hPa height pattern from 20-90N.

AD: Leading EOF of the 1000 hPa height pattern from 70-90N.



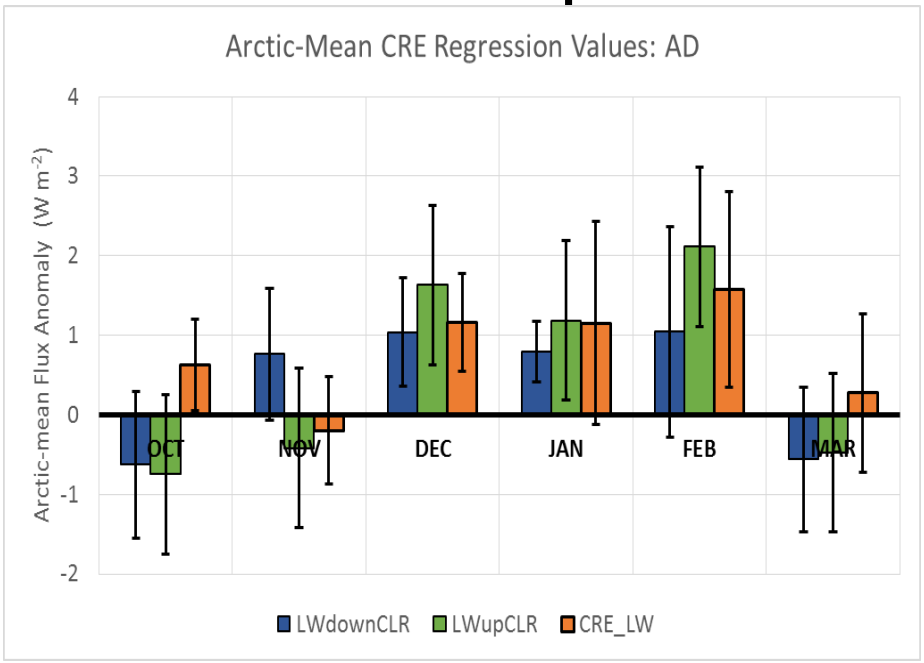
Zonally symmetric



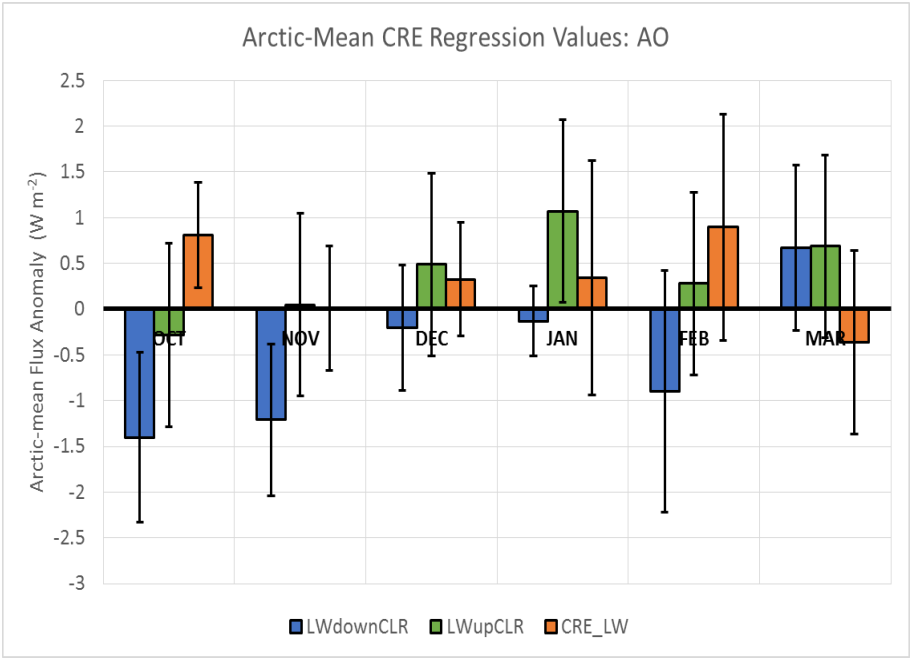
Zonally asymmetric

Any way the wind blows: Circulation and the Arctic Surface Energy Budget

Arctic Dipole



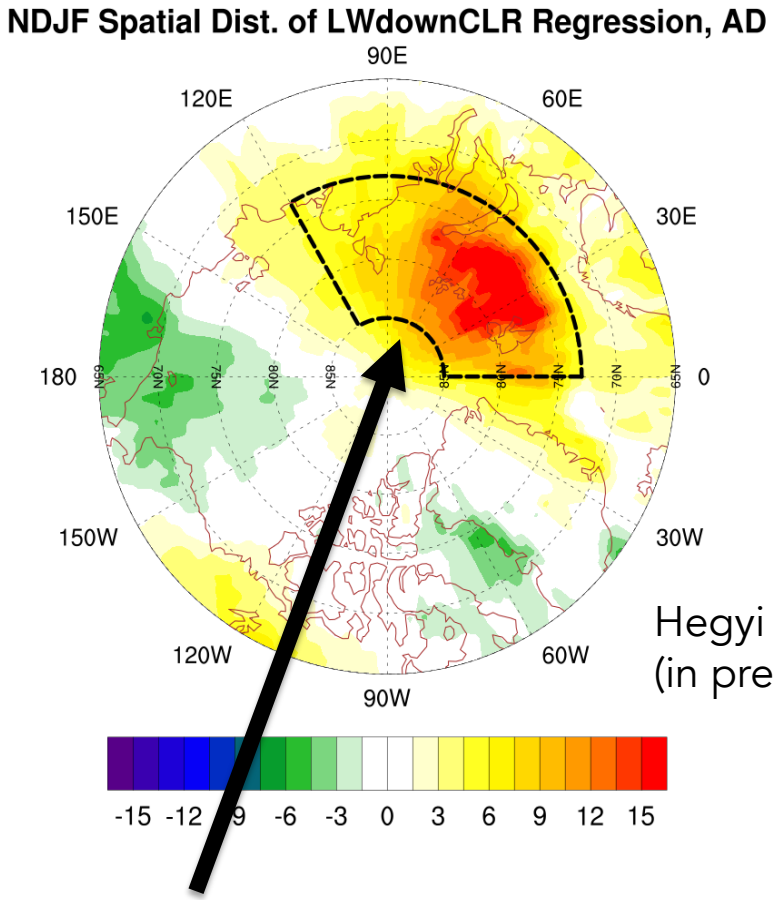
Arctic Oscillation

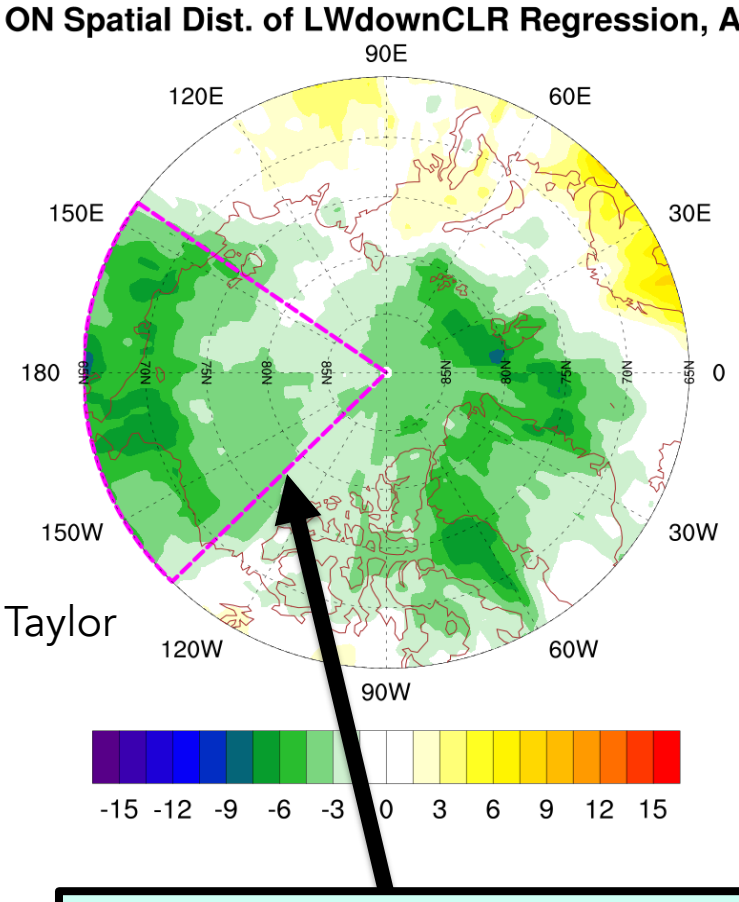


Robust, domain averaged associations between the Arctic circulation and the surface radiation budget.

Hegyi and Taylor (in prep.)

Any way the wind blows: Circulation and the Arctic Surface Energy Budget



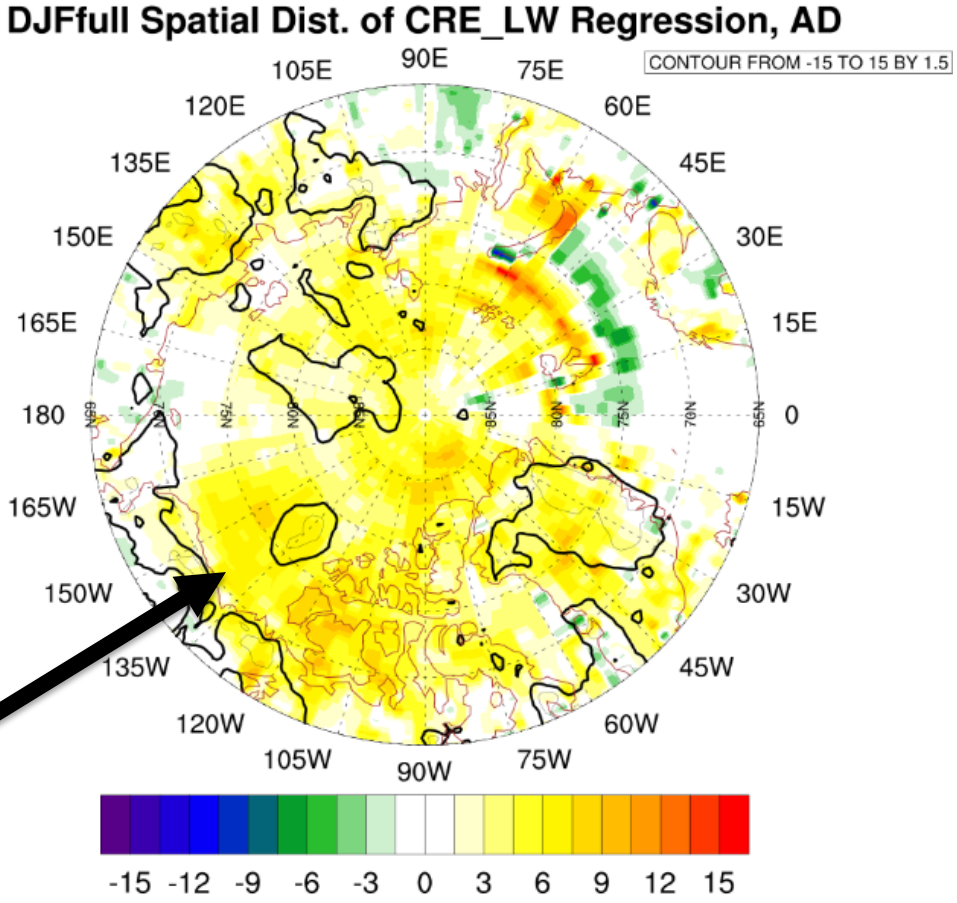


Hegyi and Taylor (in prep.)

Positive AD: Significant positive clear-sky downwelling LW anomaly.

Positive AO: Significant negative clear-sky downwelling LW anomaly.

Any way the wind blows: Circulation and the Arctic Surface Energy Budget

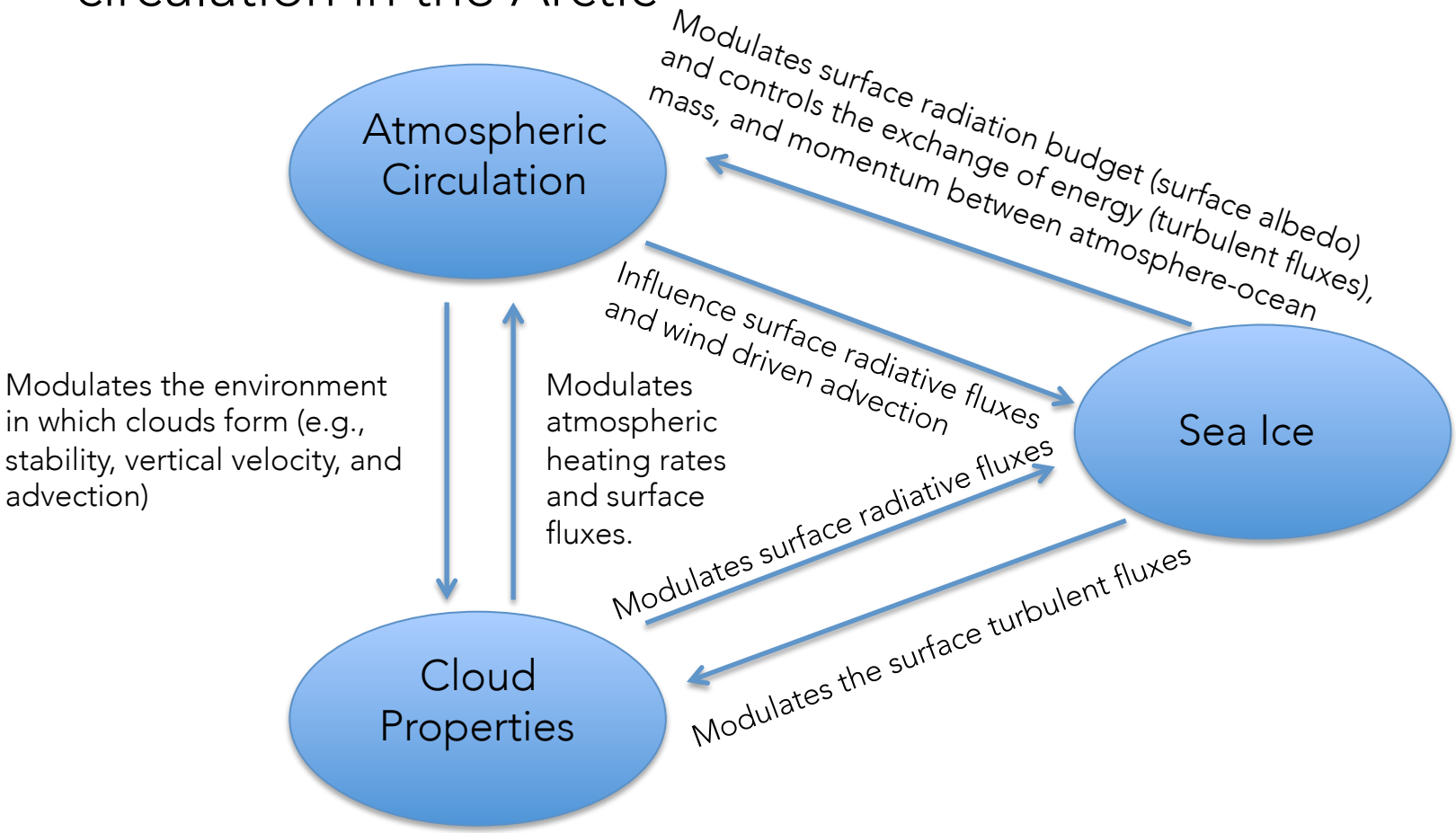


Positive AD: Significant positive surface LW CRE anomaly during winter.

Hegyi and Taylor (in prep.)

How do we reach the finish line?

Understanding the coupling between the cloud and circulation in the Arctic



In the Arctic, we cannot consider the interactions between clouds and the circulation without considering the sea ice state because sea ice influences both clouds and circulations.

In closing…

We are pursing answers to mysteries of the Arctic and encourage you to join us.

With the aid of NASA satellites, data fusion, field missions, novel analysis techniques and collaboration, we are poised to make significant progress in Arctic climate science in the coming years.

What happens in the Arctic doesn't stay in the Arctic.

It affects us all.

Questions?